Learning without Boundaries

Virginia Department of Education

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Virginia Department of Education

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FOREWORD

Governor Timothy Kaine and Superintendent of Public Instruction Patricia Wright launch Virginia on iTunes U in Richmond on April 7, 2009.

U.S. Chief Technology Officer Aneesh Chopra and Superintendent of Public Instruction Patricia Wright announce winners of the Virginia Mobile Learning Apps Development Challenge in Washington, D.C. on June 27, 2009.

In a recent Consumer Electronics Association study, teens between the ages of 13 and 17 were asked about technologies they use for personal or school reasons. A remarkable 82 percent use cell phones more than any other electronic product. This finding suggests we need to look beyond the debate about whether wireless handheld devices such as cell phones, iPods, global positioning systems (GPS) or personal technologies are appropriate for teaching and learning. Instead, we should understand how to leverage these pervasive technologies for next-generation learners, the conditions necessary for effective integration, and the unique opportunities these devices afford.

With these points in mind, Virginia launched the Learning without Boundaries initiative; it seeks to understand the technical, social, and policy implications of integrating wireless handheld devices in schools. Furthermore, the initiative is grounded in the knowledge that tools alone are not sufficient for effective integration—cutting-edge applications, engaging media-rich content, and professional development are essential.

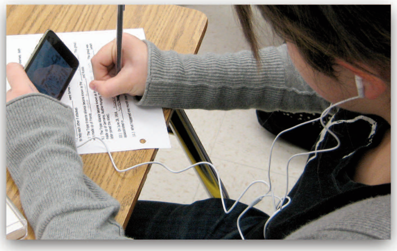
This report represents a snapshot in time. The project will continue to evolve as new questions and technologies emerge. Visit www.lwbva.org for the most current information about this initiative.

Patricia I. Wright, Ed.D.
Superintendent of Public Instruction

"The social impact of embedded computers may be analogous to two other technologies that have become ubiquitous. The first is writing, which is found everywhere from clothes labels to billboards. The second is electricity, which surges invisibly through the walls of every home, office, and car. Writing and electricity became so commonplace, so unremarkable, that we forget their huge impact on everyday life. So it will be with ubiquitous computing."

(Weiser & Brown, 1996)

INTRODUCTION



The Commonwealth of Virginia's Learning without Boundaries (LwB) initiative was launched with support from the Governor's Productivity Investment Fund (PIF), which partners with Virginia agencies to identify, catalyze, and implement innovative solutions that generate a simpler, more effective government for the benefit of the state's citizens. To that end, LwB explores how mobile handheld devices can augment desktop and laptop computers—and perhaps provide a low-cost alternative. The project has been expanded to include the development of media-rich content and specific applications for these devices to help meet the needs of Virginia's learners.

LwB strives to understand the potential benefits and challenges of expanding the learning environment beyond the confines of the traditional classroom through wireless mobile handheld computers. The goals are to (1) help elementary and secondary students develop appropriate strategies and sufficient practice to improve fundamental knowledge in target areas and (2) increase problem-solving skills using a range of emerging technologies for communication and computing. Specifically, LwB seeks to understand the technical, social, and policy implications of these technologies. The Virginia Department of Education provides guidance and strategies to help school divisions integrate these technologies into teaching and learning.

LwB leverages distinct, but related, research-based projects to study how wireless mobile technologies can be integrated effectively into teaching and learning; consequently, the individual projects are at varying stages of implementation. This report demonstrates how one-to-one computing—via mobile handheld computers—can bring exciting and potentially powerful innovations to teaching and learning. It also illustrates, however, the significant challenges researchers and policymakers must address to maximize the potentials and minimize the weaknesses of the projects.

LEARNING WITHOUT BOUNDARIES

WIRELESS TECHNOLOGIES: A LITERATURE REVIEW

In the modern elementary and secondary classroom, it is highly probable that students have used technology during a lesson or at least heard about the types of technologies available for learning. A more likely scenario is that children have had wider experiences and are more adept users of technology outside the classroom, where their access to mobile phones and portable gaming devices initiate, expand, and sustain social relationships (Evans, 2008; Shuler, 2007).

In their work constructing ethnographies of youth and new media, Mimi Ito and her colleagues (2008) distinguish between "friendship-driven" and "interest-driven" practices and networks. The former are the loosely collected groups of peers who leverage wireless mobile technologies, such as cell phones, to maintain social relationships—these networks are merely extensions of existing connections. On the contrary, interest-driven networks are strongly connected to technology and, most noticeably, arise when one or more members of a loosely coupled community begin to demonstrate expertise and direction that formalize knowledge and relationships. A good example is the interest-driven networks that emerge around popular, online, massive multiplayer games such as *World of Warcraft* and *The Sims* (Salen, 2007).

Technology, then, becomes both the focus and medium for forming and sustaining interest groups, with an agenda to generate useful knowledge valuable to members of the community. Learning without Boundaries seeks to leverage this phenomenon of collaborative knowledge by engaging teachers and especially students in domain-specific activities to spur interest-driven networks of learning.

As cited in a recent white paper (Shore, 2008), "Electronically-enabled experiences fill daily life at home, at work, and in our communities. This trend is likely to accelerate" as the sophistication and availability of such devices increases (p. 4). Adding to this discussion is another prominent scholar in the field, James Paul Gee (2008), who notes that media use by children ages 8-10 is already a part of their daily activities: "On average per day, children spend 37 minutes using computers, 65 minutes playing video games, 59 minutes listening to music, and 197 minutes watching TV" (p. 14).

The challenge here is twofold. On one hand, children and youth spend only a small portion of their waking lives in formal learning environments (Bransford, Brown, & Cocking, 2000). Consequently, educators are hard pressed to find meaningful learning experiences that reflect state and national standards of learning (specifically in the United States). On the other hand, as hinted above, the type and uses of technology in the formal classroom are often inferior compared to the situations children encounter at home. Although a digital divide may still exist with regard to higher-end desktop and laptop computers, the saturation of mobile phones, portable gaming consoles, and personal media devices provides students with ample exposure to sophisticated computational and communication devices. As Gee (2008) observes, "Many elementary [and secondary] school children are gamers and emerging tech-savvy digital natives. They crave engaging experiences with new technologies, and today they want to learn socially and collaboratively, using digital tools that allow them to participate in learning communities and to produce media and knowledge" (p. 29).

One-to-One Computing

Computer technology has proliferated rapidly in the U.S. public school system over the last 20 years. According to the National Center for Educational Statistics (NCES), public schools with Internet access rose from 35 percent in 1994 to 100 percent in 2003, requiring districts and schools to train teachers to use this new resource effectively. In 2003, 82 percent of schools provided professional development to help teachers integrate the Internet into curricula. In addition, the nationwide ratio of students per instructional computers increased significantly from 12:1 in 1998 to 4:1 in 2003 (Parsad & Jones, 2005).

Furthermore, since the introduction of the Apple Classrooms of Tomorrow™ project in 1985, the last quarter of a century has seen a steady increase in the number, scope, and sophistication of one-to-one computing, or ubiquitous computing, initiatives that now stretch from California to Maine; these programs range from fewer than 100 computers to more than 100,000 (Connerty-Marin, 2009).

While this increase has followed a steady, albeit steep, linear progression, researchers believe the nation will soon reach a technological *tipping point*, which "may represent as great a paradigm shift as the invention of writing itself" (Bull, Bull, Garofalo, & Harris, 2002, p. 7). This point will signify a rapid expansion of situations in which every student has a computer: one-to-one portable computing.

Advocates believe one-to-one computing programs could transform teaching. Others see this promise as simply another *oversold fad*, which is, at best, a drain on perpetually limited education budgets and, at worst, a distraction from more substantive education (Brown, 2003; Cuban, 2001; Oppenheimer, 2003; Papert, 1980, 1993; Shuler, 2009; Stager, 1995). This dichotomy makes documenting and disseminating the best uses of one-to-one computing strategies critical to ensure enhanced teaching and learning (Bull, Bull, Garofalo, & Harris, 2002).

While researchers and evaluators have attempted to document the impact of one-to-one technologies on students, teachers, schools, and communities, recent studies encourage additional research to identify typical and exemplary practices and determine the necessary conditions for effective implementation (Lemke & Martin, 2003; Penuel, 2005; Shuler, 2009; Zucker, 2004).

Examination of one-to-one computing should be guided by a set of key research questions:

- What are the technical, social, and policy challenges of using mobile handheld computers in teaching and learning?

- From the teachers' and administrators' perspectives, what is the added value of using mobile handheld computers to enhance effective learning environment attributes?

- According to teachers and students, what facilitates or hinders teaching in a mobile handheld computing environment?

Generally, computer-processing power doubles roughly every 18 months, while costs remain constant or decrease—this observation is known as Moore's Law. As a result, computing costs have decreased dramatically over the last five years, making large-scale one-to-one computing projects more feasible. Evidence of this trend is apparent in Henrico County, Virginia, which has distributed 25,000 laptops, attaining one-to-one ratios on a previously impossible scale; likewise, the state of Maine has achieved one-to-one computing by acquiring more than 100,000 laptops (Connerty-Marin, 2009; Silvernail & Lane, 2004; Zucker & McGhee, 2005). These ubiquitous computing projects have become rich sources of experience and research data, which could inform states, districts, and schools as they move toward one-to-one instructional models (Zucker, 2004, p. 9).

While laptops began the ubiquitous computing movement, handheld computers are the latest vanguard instruments. It is critical, therefore, to examine how teachers have successfully integrated these devices into the classroom on a one-to-one basis:

- What opportunities are possible in a one-to-one situation that would not be plausible otherwise?

- How do teachers and students use handhelds to accomplish tasks?

- What do they perceive as the strengths and weaknesses of this new instructional model?

- How have teachers been able to take advantage of the new opportunities to expand and explore teaching?

- What facilitates or hinders their instruction in this environment?

Answers to these questions will help teachers and administrators push the limits of classroom possibilities and avoid reinventing the wheel.

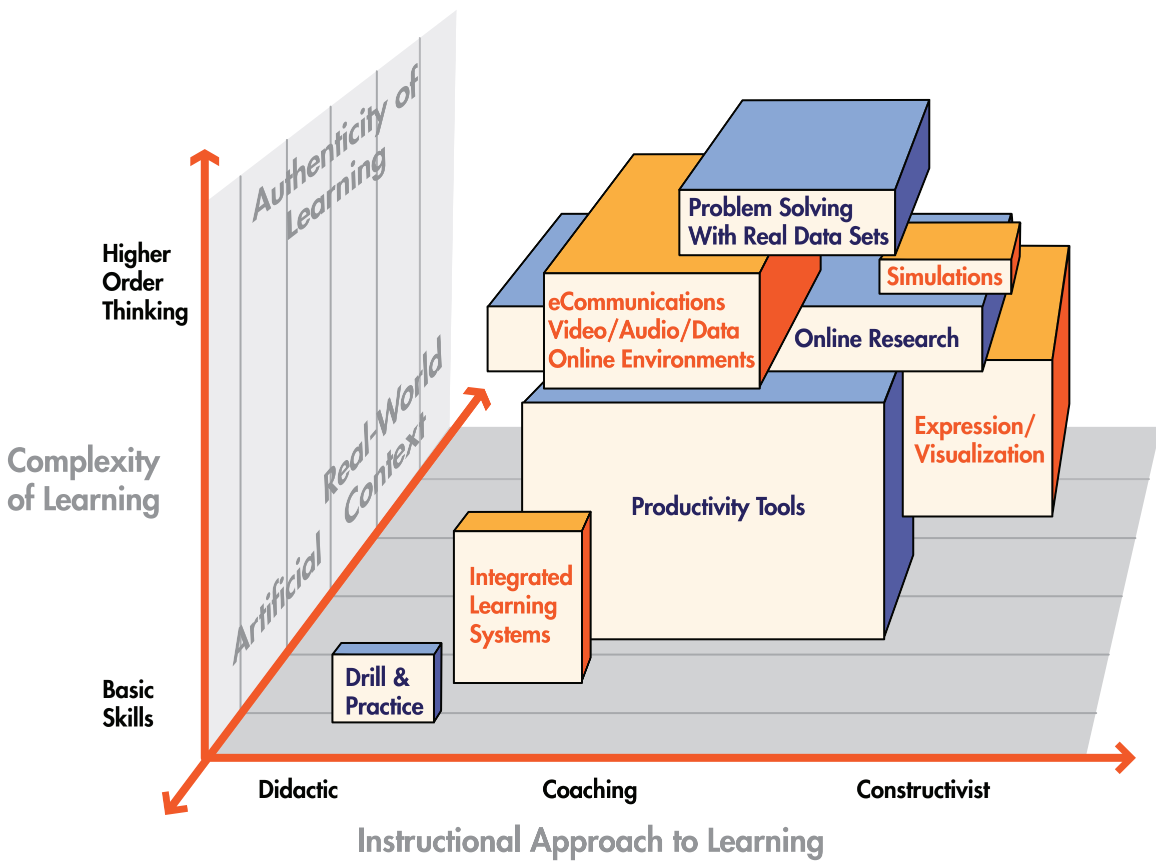
L E A R N I N G   W I T H O U T   B O U N D A R I E S

CONCEPTUAL FRAMEWORK: CATEGORIZING THE DATA

Framework One: Range of Use

Studies of classroom technology must be grounded in a framework, such as Figure 1 developed by the North Central Regional Educational Laboratory (NCREL). The Range of Use Chart was the first organizational framework to identify classroom uses congruent with the existing cognitive research that facilitate advancements in student learning (NCREL, 2000).

Figure 1. NCREL Range of Use Chart



The chart identifies eight categories of classroom technology that fit within three broader categories: instructional approach, complexity of the learning activity, and authenticity of the learning activity (NCREL, 2000). Three taxonomies provide a contextual structure to the common applications of classroom technology:

1. What uses of technology support thinking and learning, from the simple to the complex? (Y axis)

2. Which instructional approaches work most effectively with which technology applications—and to what effect? (X axis)

3. Which technology applications can be springboards to real-world context for student learning? (Z axis)

Framework Two: Added Value

Sara Dexter (2002) suggests several principles for educational technology integration and implementation principles; one of these is *added value*. Technology offers added educational value when it allows teachers and students to teach and learn in ways otherwise impossible—in other words, when it enhances, expands, and augments students' and teachers' actions and interactions within the classroom.

Specifically, Dexter proposes that technology adds value to educational processes in three broad areas: (1) accessing data, (2) processing information, and (3) communicating knowledge. In the one-to-one computing context, this added value might be represented by enhanced abilities to find and filter critical information from an Internet search, conduct formative assessments in real time—enabling individualized instruction, or create online learning communities that allow students to communicate inside and outside the classroom with peers and experts around the globe.

Framework Three: Effective Learning Environment Attributes

The effective learning environment attributes proposed by John D. Bransford, Ann Brown, and Rodney Cocking (2000) comprise a third organizational framework. In 2000, the National Research Council (NRC) posited four interrelated attributes (see Figure 2) that could be viewed as design principles for fostering effective learning environments: (1) learner centered, (2) knowledge centered, (3) assessment centered, and (4) community centered (Bransford, Brown, & Cocking, 2000; Bransford, Brophy, & Williams, 2000). Each of the four learning environment attributes leads to a series of questions about the effectiveness of handheld devices.

Figure 2. Four Attributes of an Effective Learning Environment

The learner-centered environment makes connections between the students' existing knowledge, skills, attitudes, and beliefs and the current learning situation (Bransford, Brown, & Cocking, 2000):

- Do ubiquitous handhelds help teachers reveal students' previous knowledge when accessing, processing, or communicating information?
- If so, how do handhelds empower teachers to make connections between this knowledge and the lesson at hand?
- How does the presence of handhelds help teachers build upon the conceptual and cultural knowledge when accessing, processing, and communicating information?

The knowledge-centered environment provides explicit and implicit guidance and clarification on what is taught, why it is taught, and what mastery of this knowledge looks like (Bransford, Brown, & Cocking, 2000):

- What added value do the handhelds provide the teacher to facilitate this process?
- When accessing data, do the handhelds increase clarification of the relevance of the lesson (why it is taught)?

Do the handhelds increase the teacher's ability to teach with understanding, thereby increasing the likelihood of transfer, or does it increase or promote the memorization of disconnected facts (process)?

- Do the handhelds facilitate students' metacognition in any way?
- When the teacher is communicating knowledge, do the handhelds facilitate understanding and representations of mastery or competency?

The assessment-centered environment should allow students to improve their thinking, help students understand their own progress, and help teachers identify potential remediation problems that would not be apparent without the assessments (Bransford, Brown, & Cocking, 2000):

- Does the presence of one-to-one handhelds provide added value in formative assessment, providing increased opportunities for continuous, but unobtrusive, feedback on students' understanding?

- Do the handhelds provide increased synchronous and asynchronous learning opportunities in which increased student-teacher interaction helps students revise their thinking?

- Are existing assessments based on memorizing isolated facts and concepts or on a deeper understanding—and how do the handhelds facilitate or hinder this process?

The community-centered environment establishes classroom norms and makes connections inside and outside the classroom that support the core learning values of the school and community (Bransford, Brown, & Cocking, 2000):

- What added value, if any, do the one-to-one handhelds provide the learning environment in creating a more community-centered classroom?

- How do the handhelds interact with the existing norms present in the classroom and school community? For example, are the handhelds used to foster a competitive or a cooperative community?

- Do the handhelds create more or less student-teacher interaction, or are the handhelds an isolating influence on individuals?

- Do the handhelds provide added value in making connections to a broader community outside the classroom or school? For example, do the handhelds increase communication or strengthen the connection between the students' parents and school?

- Are parents more aware of their children's schoolwork and understanding as a result of the handhelds?

- Do the handhelds facilitate communication with content experts outside the school?

LEARNING WITHOUT BOUNDARIES PROJECTS

iLearn

The iLearn project explores the opportunities and challenges of using an iPod touch as a teaching and learning tool in middle and high school settings. The following summary describes the first round of data collection, in which every student in targeted media and language classes received an iPod touch. In addition, an Apple Mobile Learning Lab with Digital Media Creation Kit served as a multimedia center for two of the three classes. The iPods and Mobile Lab were used to develop multimedia projects that aligned with the Virginia Standards of Learning and that emphasized student creativity and direction.

With funding from Governor Kaine's Productivity Investment Fund and the Virginia Department of Education, Radford City Public Schools collaborated with the GAMeS Lab at Radford University to purchase 135 iPod touch handhelds (see Figure 3) and an Apple Mobile Learning Lab with 20 MacBook laptops (see Figure 4).

Figure 3. Apple iPod touch

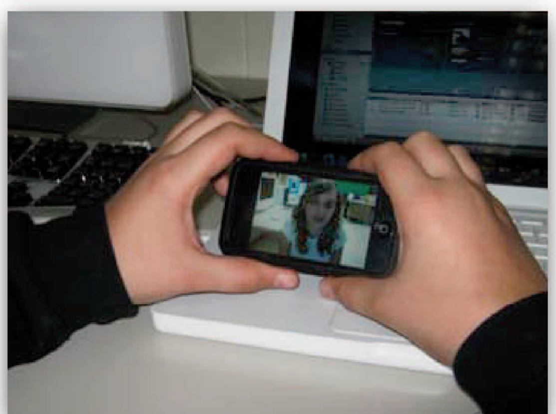


Figure 4. Apple Mobile Learning Lab

In addition, hardware and software were purchased to support the project's management and instructional objectives:

- One-terabyte Time Capsule for data storage and backup
- Digital Media Creation Kit, including video and still cameras
- AppleCare for all machines
- Apple Media Series for iWork and iLife
- Incase Protective Covers for all iPod touches
- Final Cut Express and iWork software

Class Activities

The iPods primarily were implemented across three classes: (1) Introduction to Media (grade 8), (2) TV Production (grades 11-12), and (3) Spanish (grade 10). Within these three classes, two distribution models were used: (1) 24/7 access to the machines (the two multimedia classes) and (2) in-class access only (Spanish).

Multimedia classes. The initial activities in the multimedia classes started with the basics. The teacher demonstrated the iPod touch functions (e.g., turning on and off, sleep mode, scrolling, zooming, navigating, music and video controls) and discussed proper care and use. The students also learned the most common iPod uses and how to import a CD, transfer media from the computer, sign up for an iTunes account, and download applications.

As students became more familiar with the iPod, activities changed accordingly. The participating teacher and students produced and disseminated multimedia products related to iPod etiquette, the students' favorite apps, and Internet safety. Each activity followed this general process:

- Listen to "Safety with Mobile Devices" podcast
- Complete the evaluation worksheet (see Figure 5)
- Read journal article about cell phone and iPod etiquette
- Work in groups to develop rules for safe and proper iPod use

- Use Keynote to create presentation
- Use iPhoto and Photo Booth for digital photos
- Add voiceover and music in GarageBand
- Present finished projects to class and download to iPod for viewing (see Figure 6)

Figure 5. Student Evaluating Podcast

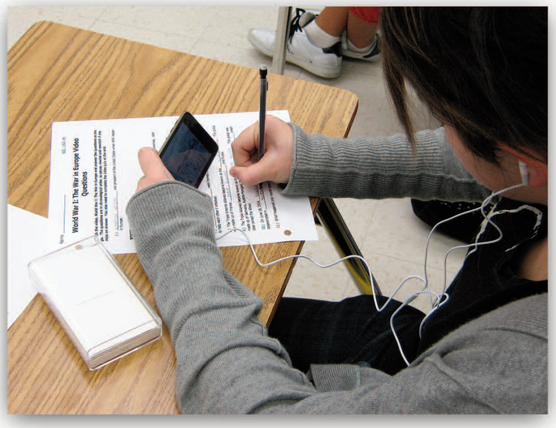


Figure 6. Viewing Student-Created Podcast

As the project progressed and the students needed less help with the iPods' functions and use, the teacher also began incorporating the iPods more into classroom curricula. Students had to demonstrate their understanding of different iPod functions and transfer previously created videos to their iPods. In addition to these activities, the TV Production class used the iPods to showcase student-created videos and photographs, take notes, review for exams, and download applications from the iTunes Store.

Spanish classes. The Spanish teacher used the iPods primarily as an individualized listening comprehension assessment tool. The teacher distributed the iPods in class and had the students watch a podcast. The students then responded on their iPods to multiple-choice questions pertaining to the viewed podcast. A Google Spreadsheet immediately displayed the students' performance on each item without revealing individual names. In this way, the teacher and students used the iPods as an individual and a classroom response system.

Technical, Social, and Policy Implications

Safe learning environment. The biggest concerns of administrators and teachers are students accessing inappropriate material (e.g., pornography, explicit song lyrics, communications with online predators) and the associated liabilities, such as legal actions from parents. Administrators have tackled these risks from a two-pronged approach: (1) parents sign an appropriate-use document assuming responsibility for their children's use of the machine off school grounds and (2) restricting wireless Internet access to specific classrooms and times.

A related challenge is the goal of creating a safe learning environment while maximizing the use of handhelds. Schools understandably position themselves on the side of security and safety, often at the expense of exploring these powerful tools for teaching and learning.

Teacher *technophobia*. A second significant challenge is the anxiety of some teachers to explore emerging technologies. Most teachers want to feel comfortable and confident with a technology prior to integrating it into the classroom; however, teachers generally do not have enough time to keep up-to-date with emerging technologies like mobile handhelds.

In part, this discomfort occurs due to a reversal in the traditional teacher-student relationship. Historically, teachers have been the experts, while students are the novices. In the case of emerging technologies, students frequently tend to be more comfortable and knowledgeable than the teachers.

Schools must acknowledge this phenomenon and help train teachers in emerging technologies. Otherwise, valuable learning opportunities will be squandered, or worse, the resulting barriers between teachers and students could lead to classroom-management problems.

Lack of standards-based applications. Most software-based iPod resources or applications presently are engaging and moderately interactive with embedded assessments; but, they are limited in terms of aligning with existing standards-based curricula. The number of applications, however, is growing daily. Only a year after creating the App Store, Apple has approximately 65,000 apps available for download (Kane, 2009). As more developers enter this area of software development, the potential for highly interactive and immersive games and applications has larger implications for content delivery and learning.

The level of complexity and immersion in the latest entertainment computer games—*Grand Theft Auto, Halo, Call of Duty*—has significant implications for the future of education (Gee, 2003). Researchers at Radford and other universities currently are designing games and researching how to leverage these immersive environments to generate one-to-one computing in classrooms.

Timely, relevant, and engaging resources. The multisensory access to timely and relevant material with embedded feedback loops allows students to revise their thinking and increases the ability of teachers to provide individualized instruction and remediation or reteaching. The one-to-one handheld classroom increases student engagement and individualized instruction across cases, thereby enhancing learner-centered and knowledge-centered attributes.

The iPods, in conjunction with Web sites such as iTunes U, allow students to access embedded video and audio clips, interactive exercises, animations, and photographs. These resources tend to make topics more relevant to students.

In addition, the amount and variety of available information is astounding—all accessible through a simple Google search. The combination of massive databases and algorithms allows anyone with an Internet connection to keyword-search millions of Web sites on any subject imaginable. This searching-and-mining capability will only increase as the technology improves.

These resources expand exponentially every day. For instance, the Google Books Library Project is working with repositories to digitize entire book and document collections. In the future, it is possible that every extant piece of symbolic knowledge produced by the human race will be online in a searchable format—that is, every surviving book, painting, scientific theorem, and mathematical formula. One-to-one computing can deliver the corpus of that knowledge to each individual student in just seconds.

The online resources are not only more relevant and timely due to the interactive and multimedia presentations, they are more engaging. Research suggests that this multisensory access produces high levels of student engagement and active learning strategies and work habits (Rockman, 1997; 1998; Ricci, 1999; Kerr et al., 2003; Russel et al., 2004; Jeroski, 2003; Ross et al., 2003; Efaw, Hampton, Martinez, & Smith, 2004; Silvernail & Lane, 2004; Zucker & McGhee, 2005; Harris & Smith, 2004; Trimmel & Bachmann, 2004; Turnbull & Gilmour, 1991).

Instant feedback. The audio and video feedback delivered via the one-to-one handhelds provides two benefits: (1) a shortened feedback loop at the student and classroom level and (2) a mechanism for formative and ongoing assessment. A typical teacher-student feedback loop can be dissected into four steps: (1) action, (2) feedback on the action, (3) reflection upon the feedback, and (4) revised action or revision. For some assignments, this process can take two or more days.

One-to-one computing can shorten the feedback loop and add value not only to students' revised thinking but also to the ongoing or formative assessment of the class-knowledge state. As recorded in a study of the iLearn project, the individual student and class-knowledge state feedback loops were decreased to a matter of seconds. Shortening the length of the circular causality feedback loop with multisensory, engaging, game-like formats is a potentially transformative added value.

A potential byproduct of this shortened feedback loop is a significant lightening of the teachers' time-intensive assessment loads. In a one-to-one classroom, well-designed software can allow students constantly to view up-to-the-second assessments. This has the potential of significantly shortening the feedback loop inherent in any learning situation.

These real-time formative assessments enable individualized instruction, thereby targeting needed areas of remediation within a curriculum. More importantly, they empower students to monitor their own learning via substantially increased opportunities for feedback, reflection, and revision. Furthermore, real-time formative assessments are one of the five ways in which technology has created an effective learning environment by "increasing opportunities for learners to receive feedback from software tutors, teachers, and peers; to engage in reflection on their own learning processes; and to receive guidance toward progressive revision that improve their learning and reasoning" (Bransford, Brown, & Cocking, 2000, p. 243).

Virtual and real collaborative learning communities. In the iLearn study, participating teachers and instructional technology resource teachers (ITRT) expressed interest in collaborating, sharing, and reviewing their teaching practices with peers and changing or refining their teaching in light of this peer review. The enhanced ability to create virtual global communities of teachers and students within a one-to-one computing environment has significant implications for the future of education.

Within active and collaborative learning communities, a circular development of knowledge begins to form (Bielaczyc & Collins, 1999). As the learning community shares its collective knowledge state or understanding, individuals are motivated to acquire more knowledge, which can then be shared. This creates a self-perpetuating feedback loop that, if regulated and guided effectively by the teacher, could provide more significant and frequent opportunities for feedback, revision, and learning (Bielaczyc & Collins, 1999; Dede, 2004).

This has significant implications for the future of education and the role of the school in students' daily lives. In large districts, students spend approximately 14 percent of their time in school during a calendar year; the other 86 percent is spent in their homes and communities (53 percent) or sleeping (33 percent) (Bransford, Brown, & Cocking, 2000). As a result, educators should link learning activities to students' homes and communities. Networked technologies—such as iEARN, ePALS, and GLOBE—have the potential to strengthen these links. One-to-one networked handhelds, used in conjunction with Web 2.0 communication Web sites like Twitter, make this feasible on an otherwise impossible scale.

Technical, logistical, and administrative challenges. According to teachers, the technical conditions necessary for effective implementation of one-to-one iPods include a reliable wireless network with sufficient bandwidth to support Web-based activities and streaming video, a sufficient amount of server space to support classroom activities, and sufficient software to support the intended lesson plans. All of these conditions support student learning, which should be the goal of any teaching innovation.

Logistical challenges generally relate to instructional training and support. Teachers would like better knowledge of the software so they can experiment with innovations. They also desire more opportunities to learn and share iPod teaching strategies and innovative uses with their colleagues. In addition, they like different training formats, including a just-in-time model, to serve the learning styles of all teachers.

Administrative issues focus on clear rules and regulations for appropriate handheld use and on software flexibility. In addition to clearly defined iPod use policies, teachers need administrative backing when students violate these rules.

Radford Outdoor Augmented Reality (ROAR) Project

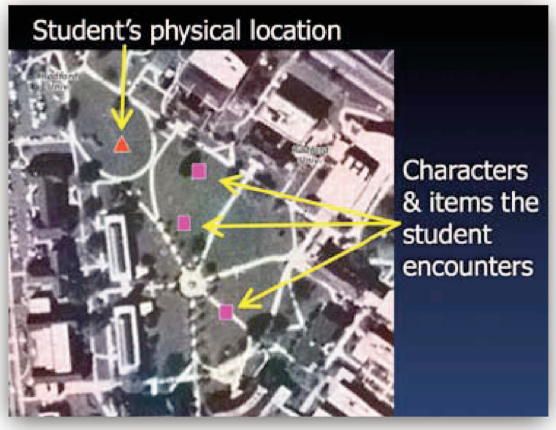
The Radford Outdoor Augmented Reality (ROAR) project is documenting the feasibility and practicality of using augmented reality to teach science to rural middle school students. The units in development, introduced in several southwestern Virginia schools, last approximately two weeks and align with specific state and national standards. These units address specific national standards and Information and Communication Technology (ICT) Digital Literacy objectives outlined by the National Research Council and the Partnership for 21st Century Skills.

Figure 7. GPS-Enabled HP iPAQ

The story-based participatory augmented reality games being developed by the ROAR team are played on an HP iPAQ Travel Companion rx5910 handheld computer (see Figure 7). They use GPS technology to correlate the students' real-world locations to their virtual locations in the game's digital world. As students walk and run around their school playground or sports fields (see Figure 8), maps on their handhelds superimpose digital objects and virtual people on real space (see Figure 9). When they come within approximately 10 feet of these digital artifacts, the augmented reality and GPS software trigger video, audio, and text files, which provide academic and problem-solving challenges as well as narrative, navigation, and collaboration cues.

Figure 8. Students Collecting Information

Figure 9. Handheld Display of Digital Objects on School Grounds



This type of interactive, mobile gaming superimposes a layer of digital resources over a real environment, augmenting students' experiences through participatory, situated, collaborative, and physically active learning experiences. The ROAR team is developing and studying augmented reality games that use mobile devices to support collaborative and interactive learning experiences. By incorporating and testing the design principles of popular video games, the team hopes to increase students' collaborative problem-solving skills, engagement, exploration of environments, and physical activity. Furthermore, technology-mediated simulations and games afford opportunities to "recruit identities and encourage identity work and reflection . . . in clear and meaningful ways" (Gee, 2003, p. 51).

As defined by Gee (2003), video games have a unique capacity to activate, recruit, and cultivate a sense of projective identity that mediates between the students' real-world identities and their virtual or game identities. Gaming environments can help students create and foster simulation identities whose goals and values intersect with and shape their real-world identities (Gee, 2003).

The transformational potential of this identity principle is integral in targeting underachieving students whose academic identity and self-efficacy is often counterproductive to science achievement (Ogbu, 2003). The goal of ROAR is to increase mobile-learning game design knowledge by researching the emotional, physiological, and social processing of mobile-game experiences.

Outbreak Unit Overview

The first augmented reality game developed by the ROAR team was *Outbreak*, which presented students with the following scenario:

> A deadly strain of a mystery disease has broken out in Thailand. As the disease quickly spreads from Bangkok to Beijing, panic begins to grip the globe. Millions of people begin to fall ill and die. Millions more begin to panic and stream out of the major cities in search of safety in the suburbs and countryside. The World Health Organization (WHO) and the Centers for Disease Control (CDC) are quickly overwhelmed, and the world's scientists plead on the Internet for the global community to pitch in and help. Everyone needs to lend a hand if we are to survive. You and your classmates—as leading experts in your respective fields of botany, zoology, and entomology—have been recruited to stop the disease.
>
> A world-famous pathologist stricken with the disease finally discovers the cure and posts a YouTube video with a dying plea for help. Unfortunately, the pathologist's video transmission is cut off, and the antidote recipe is incomplete. However, what is certain is that the antidote requires a certain combination of flora and fauna from only one site on the globe: southwestern Virginia. Only the right combination of plants and animals will complete the chemical puzzle needed to create the antidote.

The students must (1) form a hypothesis as to what completes the antidote, (2) collect the required specimens from their regional ecosystems, and (3) combine their data with their teammates to complete the puzzle.

Outbreak was based on the Virginia Standards of Learning for middle school life science (LS.4, 5, 9, 10, and 12), but the unit could easily be adapted for secondary biology students (BIO.1, 2, and 9). The unit also was based on the National Science Education Standards for grades 5-8.

In addition, the game structure and content allow teachers to make alterations based on different academic standards, content areas, and current events. The content and structure also allow for multiple entry points on which teachers may build in future iterations. Finally, the game space is designed with the potential for multiple layers of complexity.

Helping students understand the multifaceted scientific issues surrounding real-world problems is a difficult task, and learning to devise solutions to these problems is an even greater challenge. Yet, it is essential not only to prepare students to assess and resolve these problems but also to understand guiding principles for design and implementation of such curricula. The ROAR project focuses on how the emerging technology of augmented reality can foster this understanding.

Technical, Social, and Policy Implications

A study of the ROAR program reflects the findings of similar studies—namely, that the novelty and unique affordances of augmented reality games produce high levels of student engagement (Dunleavy, Dede, & Mitchell, 2009). Teachers and students also reported limitations of and challenges to augmented reality in teaching and learning.

Novelty of augmented reality learning. According to the study, the most motivating aspects of *Outbreak* were (1) the novelty of the activities compared to regular classroom learning and (2) interactive participation in team problem solving, critical thinking, and data analysis. Based upon student reports, it is reasonable to assert this can be partially, if not largely, explained by the novelty of the learning activity compared with traditional class-based activities (e.g., lectures, worksheets, and reading).

In other words, regardless of how weak or uninteresting the game design may be from learning or gaming perspectives, the participating students found *Outbreak* more interesting than their typical classroom instruction. Due to this interest level, it is difficult to accurately identify curricular-specific and technology-specific characteristics that students found engaging or disengaging.

To guard against the inherent novelty effect, which seems unlikely to fade in the short or medium terms, the research team designed an augmented reality developer's matrix to guide future design. The matrix helps developers analyze the degree to which a game (1) lends itself to an effective learning environment, (2) is engaging and effective, and (3) results in unique augmented reality affordances (Bransford, Brown, & Cocking, 2000; Gee, 2003).

Interactive team-based problem solving. Because of the one-to-one ratio, each student can receive distinct but incomplete pieces of data that require him or her to collaborate with team members to navigate the area and solve problems. In *Outbreak*, the students take on different roles (e.g., botanist, zoologist, entomologist) with different areas of expertise. While exploring the game space (e.g., school yard), they must find, analyze, and collect digital specimens within four separate habitats. Each team comprises all three roles, and each role is presented a different specimen in each habitat. The specimens have positive and negative effects associated with their use, and the students must analyze these effects as a team to determine the optimal combination. They then must select two of the three possible specimens at each data collection location in the game.

Critical thinking and data analysis. Research shows that students are most engaged by challenging video games that require sophisticated critical thinking (Gee, 2003). The ROAR team relies on this concept of *hard fun*, originally posited by Seymour Papert (2002).

Persistent design challenges. The inherent design issues often represent tensions between two critically important elements of the learning and/or gaming experience: (1) being *in* the handheld versus interacting *out* in the physical environment and (2) playing versus learning. The most challenging aspect is determining the proper balance between delivering academic and problem-solving issues—as well as narrative, navigation, and collaboration cues via the handheld—while maintaining a high level of student interaction with the surrounding physical environment. Observation and interview data for the *Outbreak* study clearly reflect that students spend the vast majority of time looking at their handhelds rather than interacting with the environment.

One of the major rationales for using augmented reality is to enrich the physical environment and create authentic scientific inquiry learning activities that more closely approximate science-based fieldwork. If students, however, are only nominally observing and interacting with the physical environment, it defeats the purpose of being outside. The research team recorded multiple examples of students being so engaged *in* the handheld game environment, they lost track of the real world *out* in the environment. For example, despite textual prompts guiding the students to the most likely location of a given specimen (e.g., "usually found in trees"), the students consistently ignored the clues and simply used trial-and-error search techniques, which consisted of walking the entire length of the area until they found the specimen.

A related challenge is to find a balance between students playing the game and paying attention to critical information. When students were asked why they did not follow the textual prompts, they reported a sense of urgency and the perception that the information was not critical to game play. Students sometimes missed critical information because of their excitement to play and their urges to compete with classmates. A partial explanation for this *racing* is a previously used linear approach to the game activities—each team would complete each step in the same sequence, resulting in multiple teams walking side by side throughout the game. This led most teams to quicken their pace, shield their answers, and whisper to avoid revealing any information that might assist the other teams (Dunleavy, Dede, & Mitchell, 2009). As a solution, the development team made two design adjustments: (1) use a nonlinear path and (2) incorporate immediate accountability by requiring the students to recall or incorporate the critical information within the game via multiple choice (least sophisticated) or game play (most sophisticated).

ITEL*RM

The Interactive Technologies for Embodied Learning in Reading and Mathematics (ITEL*RM) project helps students explore language arts and mathematics by using wireless mobile technologies with instructional multimedia and communication software. The working principle is that as children become more familiar with advanced educational software and learning technologies, teachers will be more likely to incorporate these technologies into planned and spontaneous instructional situations.

The language arts instruction focuses on context clues, synonyms, and antonyms; mathematics concentrates on division of decimals and the relative magnitude of two decimal numbers. In a recent study, the project partnered with two fourth grade, one sixth grade, and one eighth grade classroom—totaling more than 80 students.

The activities started with a small set of standards-based lesson plan instances of difficult-to-teach subjects. The learning scenarios incorporated the same technologies and learning strategies popularized by video games, personal broadcasting, and Web 2.0 technologies—the latter two hosted on Moodle, an open-source community-based course management system. The project offered professional development to help teachers continue developing lesson plans and requirements that serve their needs (see Tables 1 and 2).

Table 1. Professional Development Workshop Plan for using Moodle

What Is Inquiry-Based Learning and Why Use It in the Classroom?
• Instruction starts with a driving question, a problem to be solved. • Students explore the driving question by participating in authentic, situated-inquiry. As students explore the question, they develop an understanding of the discipline and also how to apply their understanding. • Students, teachers, and community members engage in collaborative activities to find answers to the question. • During the inquiry process, students are scaffolded with learning technologies that allow them to perform activities normally beyond their individual abilities. • Students create a set of products to address the needs of the question. These products are shared artifacts that represent the learning of the class.
Defining Electronic Portfolios and Techniques for Helping Students Develop Them
Moodle: Student-Centered Dialogue, Collaboration, and Support
• This workshop is focused on the instructor looking to engage students in the ownership of their learning. This workshop provides instructional strategies and activities using tools within [Moodle] to help you engage and to encourage student discussion and dialog. Examples will be demonstrated, and we will have the opportunity to discuss other possible ways to provide students with "ownership" in their learning.
Moodle: Reflective Learning Activities
• This workshop is focused on the instructor wishing to create outside-of-classroom reflection through projects, peer-critique and peer-review, reflective journaling, or self-assessment via personal portfolio review. Instructional strategies will be suggested and examples of how to do this will be demonstrated. We will have the opportunity to discuss how this approach can help support good practices in education and meet the higher order task of critical thinking as found in Bloom's Taxonomy.
Moodle: Planning Lessons and Using Assignments
• This workshop is focused on the instructor wishing to create online, module lesson plans and assignments to free up time in the classroom for other activities (e.g., discussion). This workshop provides hands-on opportunities to restructure your course content for use and reuse for years to come. It will also cover how to use the Assignments tools to post problem solving or skills practice online. Examples will be demonstrated, and we will have the opportunity to discuss how this approach can support best practices in education.
Moodle: Connecting Students with Content
• This workshop is focused on the instructor looking to engage students in learning. This workshop provides instructional strategies and activities using tools within [Moodle] to help you connect and engage your students in learning. Examples will be demonstrated and we will have the opportunity to discuss other possible ways to make course content available to (and resonate with) your students.
Using Games to Enrich Instruction in the Classroom

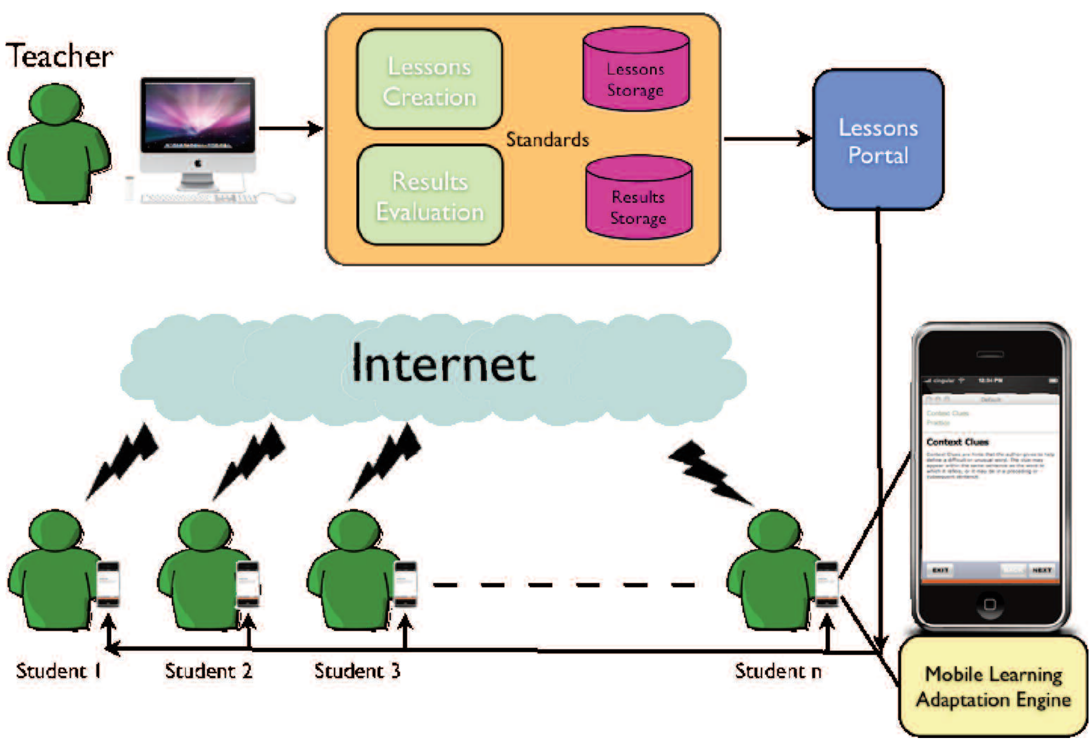
Table 2. Comparison Matrix of ICT Used for Education

	Formal						Informal
	Desktops	*Laptops*	*Tablets*	*UMPC*	*PDA*	*Media Device*	*iPod touch*
Asynchronous	High	High	High	High	High	n/a	High
Synchronous	High	High	High	High	Medium	n/a	High
1 to Many	High	High	High	High	High	Low	High
Many to Many	High	High	High	High	Low	Low	High
Availability	High	High	High	High	High	High	High
Affordability	Low	Low	Low	Medium	Medium	Medium	High
Functionality	High	High	High	High	Low	Low	High
Portability	Low	Medium	High	High	High	High	High
Customibility	High	High	Medium	Medium	Low	Low	Medium
Ubiquitous	Low	Low	Medium	Medium	Medium	Medium	High

Developing Educational Applications for Mobile Learning

One of the challenges for using mobile devices is the availability of applications and content that fits the specific pedagogical goals for the class. ITEL*RM supports a pedagogical pipeline (see Figure 10) to streamline design, development, delivery, use and evaluation of educational content on mobile multitouch platforms such as the iPod touch.

Figure 10. ITEL*RM Service Architecture



The key component of the pipeline is the Mobile Learning Adaptation Engine, which allows students to select/download content (lesson) from the lessons portal, play the lesson, and collect the results (including use statistics). The engine analyzes the downloaded content and dynamically creates the corresponding user interface/display leveraging the Model-View-Controller pattern.

Teachers may develop content without worrying about the underlying mobile technology. Standards, such as SCORM, enable interoperability and the use of freely available content development tools. The project incorporates a set of tools (mostly open source) with some translators (for different formats) to provide an integrated lesson-development environment. Lesson templates also allow teachers to package textual information within the lesson content and display it on an iPhone/iPod touch, via the Mobile Learning Adaptation Engine (see Figure 11).

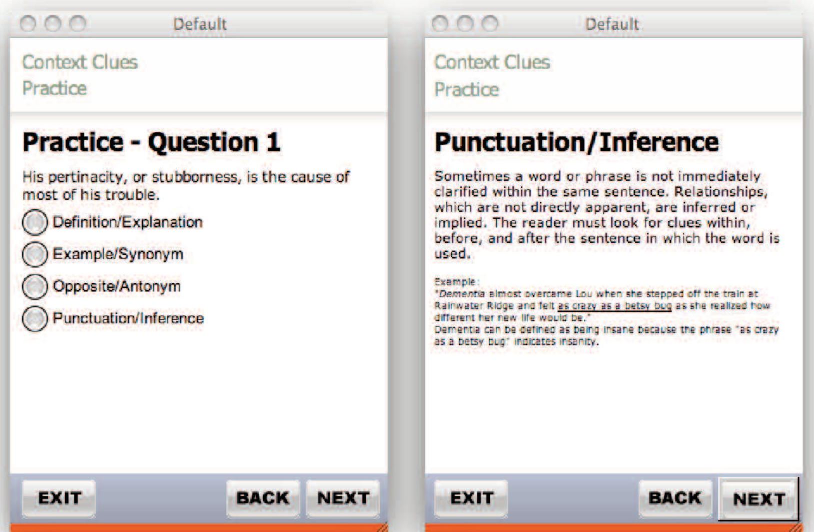


Figure 11. Customized Educational Application for iPod touch: Grade 8 Context Clues Lesson

The underlying communication architecture includes the following:

- iTunes U site, hosted by the Virginia Department of Education
- Moodle site, hosted by the local public school division
- Content/logging data delivery/storage server, hosted at Virginia Tech
- Lessons portal as a front-end Web server, hosted at Virginia Tech

The ITEL*RM project promotes the idea that technology-enhanced active learning, combined with cooperative learning, can have a profound impact on primary and secondary classrooms. Mobile multitouch devices assist in a different way and call for different outcomes. As Gee (2008) writes, "Many elementary school children are gamers and emerging tech-savvy digital natives. They crave engaging experiences with new technologies, and today they want to learn socially and collaboratively, using digital tools that allow them to participate in learning communities and to produce media and knowledge" (p. 29).

Technical, Social, and Policy Implications

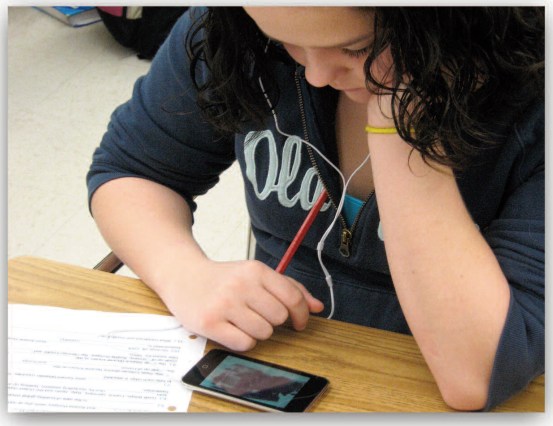


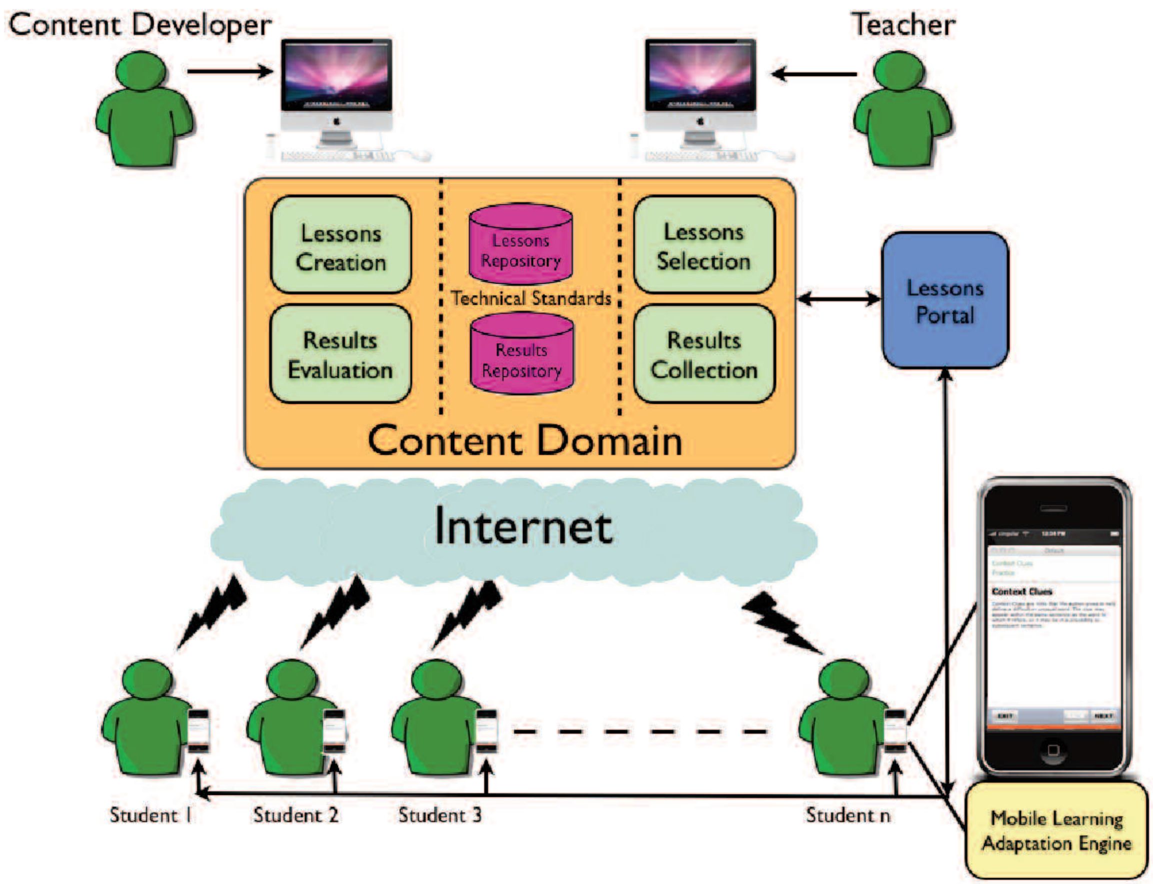
Figure 12. Fourth Grader Determining Mean Temperatures of Cities around the Globe

Differing organizational structures in elementary and middle schools. In the ITEL*RM study, the greatest obstacle to adopting and diffusing iPod touches in day-to-day teaching activities was the differing organizational structures of instruction between elementary and middle schools. At the elementary level, two fourth grade teachers were participants, with one focusing primarily on mathematics and the other on reading/language arts. They taught the same group of students over the course of a day or week; this provided the flexibility of using the devices in various curricular areas and creating buffer zones in the schedule to experiment with various instructional strategies.

The fourth grade mathematics teacher initiated a creative activity where the children tracked the temperatures of five cities around the globe using the default weather application installed with each iPod touch (see Figure 12); children explored mean, median, and mode using the different temperatures as data points. Though this may appear to be a simple application, it demonstrates the teacher's ingenuity by integrating the new devices into an existing curriculum—employing familiar materials in a unique way.

Likewise, the teacher who focused on language arts (reading) activities had her students develop podcasts advertising imaginary products. The students reviewed existing podcasts freely available on iTunes U, prepared scripts, and rehearsed their parts. Teams of students produced, edited, and published brief (less than one minute) podcasts for review of vocabulary, grammar, and pronunciation. The elementary school schedule allowed both teachers the contact time and flexibility to achieve such integration.

Figure 13. Revised Pedagogical Pipeline, Adding the Content Developer Path



By contrast, a lack of time and flexibility in the schedule created an insurmountable hurdle for the sixth grade mathematics and eighth grade language arts teachers. Although the principal and teachers were very enthusiastic about the project, the lack of flexible planning time resulted in an under use of the technology until the last weeks of the semester.

The ITEL*RM research team concluded that a significant change was needed. Initially, the team had envisioned giving teachers easy-to-use editing capabilities (see Figure 10); the revised model included a content area expert or supervisor as the primary content developer (see Figure 13). By the end of the project, it was clear that middle school teachers require more *ready-made* and easily accessible applications developed specifically for their needs. In addition, this content must be organized in a way that encourages adoption at the division level.

Technical challenges. Although schools were required to have sufficiently robust wireless networks, this clearly was not the case. Additional hardware had to be acquired to allow for sufficient wireless coverage. Another obstacle was network administration. At the school and division levels, it was not clear who should provide the support for additional equipment and training. The division currently lacks a comprehensive wireless policy for access and use.

Kids for Change—*Spore* in the Middle School Science Classroom

This project integrates commercial off-the-shelf video games, such as *Spore*, into middle school life science courses. It merges physical science, epidemiology, mathematics, computational thinking, education, and the social sciences. Students can engage in a real-world problem, work collaboratively to solve the problem, think analytically about solutions and prevention, scale their problems based on different inputs, use multiple mediums for their research, and store and document their findings and procedures as a way of sharing and learning.

Teachers can use digital games and simulations to facilitate knowledge building around topics. Nevertheless, these games simply cannot be purchased one weekend and brought into the classroom on a Monday with any hope for successful implementation. Integrating games into the classroom requires teachers to learn the games inside and out (Charsky & Mims, 2008).

Some titles, like *Spore* or *Civilization IV*, are open-ended simulation games that allow players to take many possible trajectories (Squire, 2008, pp. 170-172). In a sense, each player can play his or her own game. While this can be advantageous in some ways, it is not conducive to a classroom setting. Time is a commodity; so, playing games like *Spore* for an hour with no direct purpose could be a waste of time. As a result, teachers should plan the time carefully. Both *Spore* and *Civilization IV* can be saved at different points in the game, which allows teachers to schedule specific parts of the game during class time.

Spore

Spore and other games have been used in Virginia middle school science classrooms to reinforce many important concepts in the state Standards of Learning. One benefit is that most games and simulations can be adapted to individual learner needs (cognitive, social, physical). By permitting each student to play the game at his or her own pace, the instructor allows differentiation to occur. Students have different levels of understanding, so teachers should work individually with them. Socially, students can bring together their thoughts and discoveries about the game and feel a sense of competition. Physically, *Spore* and most other games demand that students take part in on-screen activities, which keep them engaged.

Technical, Social, and Policy Implications

Making games modifiable for practice and assessment. Teachers should develop materials that help students connect key learning concepts with the game. These materials also should assess the students' understanding of how the game illustrates, or does not illustrate, the learning concepts. This performance-based assessment comprises the responses students provide on papers and their ability to complete the game to various points.

How games and simulations can alter teaching, learning, and assessment. The biggest challenge is to keep students focused on the lesson objectives instead of just the game's mechanics. Students are not accustomed to using off-the-shelf games in science classrooms, and most likely will approach the game as they do at home—just for fun. Their normal approach is not necessarily academic and productive. So, the classroom materials and discussions are essential to the students' comprehension of the foundational knowledge they can learn from the game.

Technical considerations. In the study, the technology served the needs of the teacher and students alike. Minor considerations related to the iPod touch's battery life and the efficient use of devices in a one-to-one scenario, where classroom space is precious. The battery life was disappointing and forced the teacher to use the devices creatively from period to period. Basically, she had to recharge each device between periods, which cut into class time; also, students had to stop sessions early so the iPods could be recharged for the next class. Another solution was to turn off the wireless radio to save energy; however, in some sense, this countered the purpose of using such devices. Despite these challenges, the instructional technology resource teacher (ITRT) considered this project worthwhile.

Accepting and incorporating mobile wireless devices in the classroom. This project was a very different intervention from ITEL*RM. The project team drew from additional funding sources to provide two important assets: (1) an off-the-shelf application that met specific instructional and learning needs and (2) buy-out time—three full working days for the teacher to familiarize herself with the application and revise a lesson plan and assessment. As a result, she could incorporate *Spore* into a lesson plan.

The social implications of this study were twofold. First, by providing each student with a device and demonstrating the advantages of technologically enhanced lessons, the teacher was able to overcome the parents' initial apprehensions about children playing *games* in the classroom (see Figure 14). Second, adequate funding allowed the middle school teacher time to construct a thorough lesson plan and evaluation scheme that met state standards and maintained the integrity of her practice. This was particularly important in gaining the permission of the division science supervisor. The teacher was required to present the entire lesson plan and evaluation metrics to the supervisor prior to beginning the pilot project. Moreover, the supervisor made in-class and follow-up visits to observe and comment. The response was very positive and convinced the supervisor that a sufficiently funded broader pilot would be worthwhile.

The lesson learned in this project was that social and policy considerations must be addressed prior to or in concert with the technological issues. In contrast to the ITEL*RM study, Kids for Change demonstrated that coordinating policy, technological, and social challenges can produce innovative educational interventions and impressive results.

Figure 14. Teacher (back of room in red) Leading the Class in Game-Based Science Learning Using *Spore*

Without question, *Spore* and other games can engage middle school science students. With the proper scaffolding, students playing the game can identify examples of what they had learned in class. Students often need to be prompted during discussions to fill in learning elements that are absent in the game. This can be achieved through teacher questions and student discussions. A multiple-choice pretest and posttest will be used in the future in addition to the Expert Log. Certainly, students learn through processing the simulation and cooperatively sharing ideas.

L E A R N I N G   W I T H O U T   B O U N D A R I E S

LEARNING WITHOUT BOUNDARIES: EMERGENT PROJECTS

Virginia on iTunes U

On April 7, 2009, the Virginia Department of Education launched Virginia on iTunes U—in collaboration with Apple, Radford University, Blue Ridge Public Television, and Thinkfinity. This portal, located in Apple's popular iTunes Store, enables students, teachers, and families across Virginia to access, create, and share educational media-rich content and resources anytime, anywhere.

Virginia on iTunes U has quickly emerged as one of the leading K-12 iTunes U sites, as evidenced by requests from Minnesota, Florida, North Carolina, and other states for guidance in developing similar sites. The Department of Education's Office of Educational Technology developed a rigorous process for contributing content to ensure all content reflects the highest standards for quality and relevance. A guidance document includes information about copyright, metadata standards, rubrics for assessing the appropriateness of content, file specifications, and other relevant information. Weekly usage reports demonstrate that the number of downloads from the site has increased steadily each week since the launch.

The Office of Educational Technology has worked diligently to form alliances with content providers throughout the Commonwealth and beyond. Virginia's public television stations and nonprofit organizations, such as the Professor Garfield Foundation and George C. Marshall Foundation, are joining the Department of Education and local educators to make content available. Additionally, the National Oceanic and Atmospheric Administration (NOAA) now contributes content to Virginia on iTunes U; as with all content on the site, the NOAA resources will be aligned to the Virginia Standards of Learning. Virginia on iTunes U does not simply replicate the enormous volume of resources already available on the Web; rather, it brings together high-quality resources that meet the specific needs and interests of Virginia's students and families.

Professional development. Professional development is another key component of Virginia on iTunes U. Department of Education staff have been trained to understand how mobile content can expand and enhance opportunities for learners. Staff members also have learned to develop their own high-quality podcasts. This training includes planning, creating, and managing digital media files; writing scripts;

and recording, editing, producing, and publishing enhanced podcasts. They also have learned how media players, such as iPods, can engage learners with diverse learning styles. In addition, classroom teachers and library media specialists receive similar training and support through regional training events and the Commonwealth's extensive network of instructional technology resource teachers (ITRT).

Apps Challenge

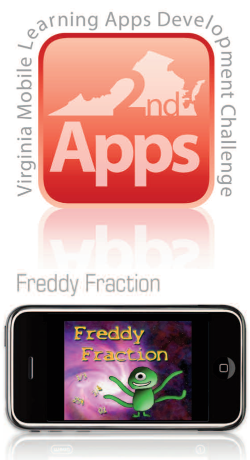
Also on April 7, 2009, Virginia Secretary of Technology Aneesh Chopra and the Virginia Department of Education issued a challenge for developers to produce mobile learning applications for the iPhone or iPod touch that engage middle school students in mathematics. Based on mathematics achievement data from the Virginia Standards of Learning (SOL) assessments and Algebra Readiness Diagnostic Test (ARDT), the following priorities were identified: computing fractions; using proportional and quantitative reasoning; converting measurements using proportions; solving multistep consumer application problems; determining equivalence relationships among fractions, decimals, and percents; and finding and ordering equivalent fractions, decimals, and percentages on a number line.

The purpose of the Virginia Mobile Learning Apps Development Challenge was not simply to add to the growing collection of iPhone and iPod touch apps but rather to meet the specific learning needs of Virginia's students. Applications had to represent and model important mathematics concepts and skills that encourage student-directed learning and enrichment beyond the classroom.

All entries were uploaded to the Apple Apps Store and made available to everyone free of charge. A distinguished panel of judges evaluated content, instructional design/pedagogy, technical/code quality, user experience, and the extent to which the app leveraged the unique capabilities of the device. Winners of the challenge were announced at a meeting of the State Educational Technology Directors Association in Washington, D.C., on June 27, 2009; project staff presented the apps at the National Educational Computing Conference held in conjunction with the event.

First Place: *Number Line* by Todd Bowden. *Number Line* is an educational game app to help students learn about fractions, decimals, and percentages by ordering equivalent fractions, decimals, and percentages on a number line. The app features multiple levels—ranging from easy to hard—where the player must drag circles with either a percentage, decimal, or fraction onto a number line in the correct sequence. If a circle is placed correctly, it will turn green and a pleasant *success* sound will play. If a circle is placed incorrectly, it will turn red and an error buzzer will sound. The player can then remove the circle from the line and try again. A score for each level is earned based on the time it takes to put all the circles in the correct order (faster is better), plus points are awarded or subtracted for correct or incorrect placements.

Future enhancements will include the ability to send high scores for each level to a Web site and view the high scores for each level on an iPhone. This will encourage students to compete against one another for the high-score spots and, in the process, learn equivalent relationships among fractions, decimals, and percentages more quickly.



Second Place: *Freddy Fraction* by Daniel Burgess, GAMeS Lab, Radford University. *Freddy Fraction* is an alien who needs your help! He was exploring a strange, foreign planet when he realized he couldn't remember where he parked his spaceship . . . Freddy is lost! Help Freddy find his way back to his spaceship using fractions, decimals, and percentages! Use your finger to guide Freddy back to his ship. Freddy needs to travel the path of fractions, decimals, and percentages. By dragging Freddy to the number equivalent to the number at the top of the right-hand column, you will help Freddy get back to his ship safely.

Third Place: *Fraction Factory* by Dave Payne, GAMeS Lab, Radford University. Enter the *Fraction Factory* and use your mathematics skills to place fractions into their correct positions. When the game begins, fraction gears move across the screen on a conveyor belt. Use your finger and drag the fraction gear to where you think it goes on the number line. Notice when you touch the fraction gear and move it left and right, a number equivalent to your current decimal appears on the number line. Use this as a guide for the most correct position to place the fraction gear. But hurry, you have only 60 seconds to put as many fraction gears as possible where they need to go! When the time is up, find out how many you put away, your average accuracy, and your rank in the Fraction Factory. Do you have what it takes to be the Fraction Factory CEO?

The Next challenge. The apps and the overall challenge process were well received by educators around the globe. In response to the overwhelmingly positive feedback from educators and additional interest by the developer community, the Virginia Department of Education plans to issue a new challenge in fall 2009. As in the first round of competition, the upcoming Apps Challenge will reflect priorities identified through a review of student achievement data.

LEARNING WITHOUT BOUNDARIES

CONCLUSION

In 1997, Judith Sandholtz and her colleagues wrote the following:

> Changing the classroom environment to include technology may not eliminate many of the age-old problems inherent in the school system and, in some cases, may exacerbate them. Limited time, pressure to cover the mandated curriculum, problems with classroom management, scarce resources, and teachers' feelings of isolation persist even in classrooms radically altered by the introduction of new technological tools (Sandholtz, Ringstaff, & Dwyer, p. 3).

Research suggests, however, that one-to-one computing has the potential to ameliorate many, if not all, of these challenges. Real-time formative assessments—made possible by one-to-one technology—allow teachers to individualize instruction, thereby targeting necessary remediation areas within the mandated curriculum (Kerr, Pane, & Barney, 2003; Rockman, 1997, 1998; Silvernail & Lane, 2004). Additionally, increased student engagement results in fewer class management problems and more student on-task time (Jeroski, 2003; Kerr et al., 2003; Ross, Lowther, Wilson-Relyea, Wang, & Morrison, 2003; Russell, Bebell, & Higgins, 2004; Trimmel & Bachmann, 2004; Turnbull & Gilmour, 1991).

Internet-capable wireless laptops and handhelds literally make thousands of powerful and easy-to-use resources available to teachers and students alike at the stroke of a key—enabling *anytime, anywhere* learning (Hill, Reeves, Grant, Wang, & Han, 2002; Ross et al., 2003; Shuler, 2009; Zucker & McGhee, 2005). Web 2.0 technologies—such as wikis, blogs, social networking, and chat rooms—have decreased teacher isolation and changed the way educators share ideas and information, formally and informally, among their peers across the hallway and around the globe (Dede, 2009; Greenhow, Robelia, & Hughes, 2009).

It is important to acknowledge that the presence of educational technology and one-to-one computing *provides only the opportunity* for added value and enhanced learning and teaching—by itself, the mere existence of a technology-rich environment is not sufficient. In fact, the one-to-one computing classroom frequently presents unique challenges and barriers to successful instruction, such as increased management problems, increased teacher workload, and difficulty linking mobile computer use to learning outcomes and standards (Hill et al., 2002; Kerr et al., 2003; Newhouse, 2001; Turnbull & Gilmour, 1991; Zucker & McGhee, 2005). Research also suggests, however, that under the right conditions (e.g., appropriate professional development, effective technical support, positive teacher attitudes and beliefs regarding implementation), a one-to-one computing learning environment can provide added value to an effective learning environment (Penuel, 2005; Shuler, 2009).

Regardless of the technology, certain aspects of the classroom will not change fundamentally but will remain necessary and critical components of any successful learning environment. According to the National Research Council, an effective learning environment should center on the learners, assessment, knowledge, and communities (Bransford, Brown, & Cocking, 2000). By focusing on the added value of one-to-one technology in the realms of mutable, yet permanent, aspects of the classroom, ubiquitous computing research will have relevance beyond the latest laptops and handheld computers, even as the one-to-one devices morph into more powerful tools. The research emphasis should be on studies that transcend the latest technology manifestations and that apply to any one-to-one environment—be it handheld, laptop, or projected holograms.

Key Considerations for Schools

- Acceptable use policies must reflect the 24/7 *anytime, anywhere* nature of mobile handheld technology.

- Educators need training in the use of emerging technologies and how mobile content can expand and enhance opportunities for individual learners.

- Educators need training to develop appropriate and useful content for mobile learning.

- Educators need time to explore and develop strategies for using specific educational games, simulations, and apps with students.

- Educators should provide curriculum connections and skill scaffolding to help students understand how to use educational games, simulations, and apps for learning rather than *just fun*.

- Parents and community members must be educated as to the value of using educational games, simulations, and apps.

- Mobile handheld applications should be evaluated for multiple attributes, including connections to state standards, engaging interactivity, team-building capabilities, critical-thinking development, and embedded feedback and formative assessment.

- Mobile handheld devices should be evaluated for characteristics such as battery life, ease of use, specific features (such as GPS), and durability.

- Technology infrastructure must include a reliable wireless network with sufficient bandwidth for various media and a sufficiently robust server to enable various types of group activities and house software needed for projects.

REFERENCES

All Web sites were available on 2 August 2009.

Bielaczyc, K. & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Riegeluth, *Instructional Design Theories and Models: A New Paradigm of Instructional Theory, Vol. II* (pp. 269-292). Mahway, N.J.: Lawrence Erlbaum.

Bransford, J., Brophy, S., & Williams, S. (2000). When computer technologies meet the learning sciences: Issues and opportunities. *Journal of Applied Developmental Psychology, 21*(1), 59-84. doi:10.1016/S0193-3973(99)00051-9.

Bransford, J., Brown, A., & Cocking, R. (2000). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academy Press.

Brown, D. G. (ed.). (2003). *Ubiquitous computing: The universal use of computers on college campuses.* Bolton, MA: Anker Publishing.

Bull, G., Bull, G., Garofalo, J., & Harris, J. (2002). Grand challenges: Preparing for the technological tipping point. *Learning & Leading with Technology, 29*(8), 6-12.

Charsky, D., & Mims, C. (2008). Integrating commercial off-the-shelf video games into school curriculums. *TechTrends*, *52*(5), 38-44.

Connerty-Marin, D. (2009). *Maine expands laptops to high school students.* Augusta: Maine Department of Education. http://www.maine.gov/tools/whatsnew/index.php?topic=DOENews&id=69205&v=article.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom.* Cambridge, MA: Harvard University Press.

Dede, C. (2004). Enabling distributed learning communities via emerging technologies. *THE Journal, 32*(2), 12–22.

Dede, C. (2009). Comments on Greenhow, Robelia, and Hughes: Technologies that facilitate generating knowledge and possibly wisdom. *Educational Researcher 38*(4): 260-263. doi:10.3102/0013189X09336672.

Dexter, S. (2002). Etips-educational technology integration and implementation principles. In P. Rodgers (Ed.), Designing Instruction for Technology-Enhanced Learning (pp. 56-70). New York: Idea Group.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7-22.
Efaw, J., Hampton, S., Martinez, S., & Smith, S. (2004). Miracle or teaching and learning with laptop computers in the classroom. *Educause Quarterly, 3*, 10-18.

Evans, M. A. (2008). Mobility, games, and education. In R. Ferdig (ed.), *Handbook of Research on Effective Electronic Gaming in Education* (Vol. 1, pp. 96-110). Hershey, PA: Information Science Reference.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Gee, J. P. (2008). *Getting over the slump: Innovation strategies to promote children's learning.* New York: The Joan Ganz Cooney Center at Sesame Workshop.

Greenhow, C., Robelia, B., & Hughes, J. (2009). Learning, teaching, and scholarship in a digital age: Web 2.0 and classroom research: What path should we take now? *Educational Researcher 38*(4): 246-259. doi:10.3102/0013189X09336671.

Harris, W. J., & Smith, L. (2004). *Laptop use by seventh grade students with disabilities: Perceptions of special education teachers: Maine Learning Technology Initiative: Research report #2*. N.p.: Maine Education Policy Research Institute, University of Maine. http://libraries.maine.edu/cre/meprip/mltiresearchreport2.pdf.

Hill, J. R., Reeves, T. C., Grant, M. M., Wang, S. K., & Han, S. (2002). *The impact of portable technologies on teaching and learning: Year three report.* Athens: The University of Georgia. http://lpsl.coe.uga.edu/Projects/aalaptop/pdf/aa3rd/Year3ReportFinalVersion.pdf.

Ito, M., Horst, H., Bittani, M., Boyd, D., Herr-Stephenson, B., Lange, P., Pascoe, C., & Robinson, L. (2008). *Living and learning with new media: Summary of findings from the digital youth project*. Chicago: MacArthur Foundation. http://digitalyouth.ischool.berkeley.edu/files/report/digitalyouth-WhitePaper.pdf.

Jeroski, S. (2003). *Wireless writing project. School District No. 60 (Peace River North) research report: Phase 2.* Vancouver, BC: Horizon Research & Evaluation.

Kane, Y. I. (2009, June 15). Seeking fame in Apple's sea of apps. *Wall Street Journal.* http://online.wsj.com/article/SB124761263919341941.html.

Kerr, K. A., Pane, J. F., & Barney, H. (2003). *Quaker Valley Digital School District: Early effects and plans for future evaluation.* Santa Monica, CA: RAND.

Lemke, C., & Martin, C. (2003). *One-to-one computing in Maine: A state profile*. N.p.: Metiri Group. http://www.metiri.com/NSF-Study/ME-Profile.pdf.

Newhouse, P. (2001). A follow-up study of students using portable computers at a secondary school. *British Journal of Educational Technology, 32*(2), 209-219.
North Central Regional Educational Laboratory. (2000). *Range of use chart.* Chicago: Author.

Ogbu, J. U. (2003). *Black American students in an affluent suburb: A study of academic disengagement.* Mahwah, NJ: Lawrence Erlbaum.

Oppenheimer, T. (2003). *The flickering mind: The false promise of technology in the classroom and how learning can be saved*. New York: Random House.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York: Basic Books.

Papert, S. (2002). Hard fun. *Bangor Daily News.* http://www.papert.org/articles/HardFun.html.

Parsad, B., & Jones, J. (2005). *Internet access in U.S. public schools and classrooms: 1994-2003.* Washington, DC: National Center for Education Statistics.

Penuel, W. R. (2005). *Research: What it says about 1 to 1 learning*. Cupertino, CA: Apple Computer. http://ubiqcomputing.org/Apple_1-to-1_Research.pdf.

Ricci, C. (1999). *Program evaluation: The New York City Board of Education Community School District Six laptop project.* New York: Metis.

Rockman, S. (1997). *Report of a laptop program pilot.* San Francisco: Rockman Et Al.

Rockman, S. (1998). *Powerful tools for schooling: Second year study of the laptop program*. San Francisco: Rockman Et Al.

Ross, S. M., Lowther, D. L., Wilson-Relyea, B., Wang, W., & Morrison, G. (2003). *Anytime, anywhere learning: Final evaluation report of the laptop program: Year 3*. Memphis, TN: The University of Memphis. http://www.myschoolpages.com/schools/wlcsd/files/359604/Laptop_Report_Yr3.pdf.

Russell, M., Bebell, D., & Higgins, J. (2004). Laptop learning: A comparison of teaching and learning in upper elementary classrooms equipped with shared carts of handhelds and permanent 1:1 handhelds. *Journal of Educational Computing Research, 30*(4), 313-330.

Salen, K. (2007). The ecology of games: Connecting youth, games, and learning. In K. Salen (ed.), *The Ecology of Games: Connecting Youth, Games, and Learning* (pp. 1–17). Boston: MIT Press.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*. New York: Teachers College Press.

Shore, R. (2008). *The power of Pow! Wham! Children, digital media & our nation's future: Three challenges for the coming decade*. New York: The Joan Ganz Cooney Center at Sesame Workshop. http://www.joanganzcooneycenter.org/pdf/Cooney_Challenge_advance.pdf.

Shuler, C. (2007). *D is for digital: An analysis of the children's interactive media environment with a focus on mass marketed products that promote learning*. New York: The Joan Ganz Cooney Center at Sesame Workshop. http://www.joanganzcooneycenter.org/pdf/DisforDigital.pdf.

Shuler, C. (2009). *Pockets of potential: Using mobile technologies to promote children's learning*. New York: The Joan Ganz Cooney Center at Sesame Workshop. http://www.joanganzcooneycenter.org/pdf/pockets_of_potential.pdf.

Silvernail, D. L., & Lane, D. M. (2004). *The impact of Maine's one-to-one laptop program on middle school teachers and students: Research report #1*. Gorham: Maine Education Policy Research Institute, University of Southern Maine.

Squire, K. (2008). Open-ended video games: A model for developing learning for the interactive age. In K. Salen (Ed.), *The Ecology of Games: Connecting Youth, Games, and Learning* (pp. 167-198). Boston: MIT Press.

Stager, G. (1995). In Australia . . . Laptop school leads the way in professional development. *Educational Leadership, 53*(2), 78-81.

Trimmel, M., & Bachmann, J. (2004). Cognitive, social, motivational and health aspects of students in laptop classrooms. *Journal of Computer Assisted Learning, 20*(2), 151-158.

Turnbull, G., & Gilmour, T. (1991). Handhelds in the Scottish primary school: Interim report. *Educational Media International, 28*(2), 63-66.

Weiser, M., & Brown, J. S. (1996). *The coming age of calm technology*. New York: Copernicus.

Zucker, A. (2004). Developing a research agenda for ubiquitous computing in schools. *Journal of Educational Computing Research, 30*(4), 371-386.

Zucker, A., & McGhee, R. (2005). *A study of one-to-one computer use in mathematics and science instruction at the secondary level in Henrico County Public Schools*. Washington, DC: SRI International.

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